Scientia Africana, Vol. 23 (No. 4), October, 2024. Pp 255-264
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IMPACT OF CLIMATIC FACTORS ON INDOOR MOSQUITO SPECIES ABUNDANCE IN RIVERS STATE, NIGERIA

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Received: 17-10-2024
Accepted: 26-10-2024

https://dx.doi.org/10.4314/sa.v23i4.22

Journal Homepage: http://www.scientia-african.uniportjournal.info
Publisher: *Faculty of Science, University of Port Harcourt.*

ABSTRACT

Mosquito abundance in sub-Sahara Africa is of great public health importance and has been linked to various infectious diseases. The aim of this study is to determine the impact of climatic factors on mosquito abundance in the study area. Indoor resident mosquitoes were caught using pyrethrum spray catch technique and identified based on morphological characteristics. Results revealed a total of 3321 mosquitoes from 16 species toinclude An. gambiaes.l., An. funestus, An. coustani, Ae. aegypti, Ae. vittatus, Ae. metallicus, Ae. stokesi, Ae. albopictus, Cx. tigripes, Cx. horridus, Cx. quinquefasciatus, Cx. andersoni, Cx. pipiens, Cx. univittatus, Cx. striatipes and Cx. Thalassius accounting for 469(14.16%), 210(6.32%), 85(2.56%), 478(14.39%), 183(5.51%), 116(3.49%), 86(2.59%), 390(11.74%), 159(4.79%), 46(1.39%), 391(11.77%), 160(4.82%), 315(9.49%), 112(3.37%), 78(2.35%) and 43(1.29%) respectively. Of the total catch, Port Harcourt recorded abundance of 1725(51.N94%) against Odual with 1596(48.06%). The impact of rainfall on the abundance of indoor resident mosquitoes revealed a positive linear relationship in Odual (y=0.2645x+128.87; R^2=0.1959) and Port Harcourt (y=0.5068x+82.2; R^2=0.387) likewise humidity in Odual (y=2.5533x-53.044; R^2=0.0592) and Port Harcourt (y=5.8259x-342.62; R^2 = 0.1373).However, a skewed relationship was noted with temperature, hence a positive relationship in Odual (y = 19.595x - 366.89; R^2 = 0.1463) and a negative in Port Harcourt (y = -27.434x + 874.19; R^2 = 0.1454). People in the study areas, are at risk of mosquito-borne diseases based on the result analysis. Understanding the impact of climatic factors on mosquito abundance is prerequisite for predicting itsdisease outbreaks, developing effective control measures and improve surveillance.

Keywords: Indoor resident mosquitoes, pyrethrum spray catch, climate, infectious diseases.

INTRODUCTION

Mosquitoes are still considered as the most dangerous flying invertebrates because their females feed on human blood and transmit diseases. They are estimated to transmit diseases to more than 700 million people annually and responsible for the death of about 1 in 17 people (Lamidi*et al*., 2019). Effective transmission of mosquito-borne disease requires successful contact between infected female mosquitoes and their hosts (Xu *et al*., 2014). Among the culicids, the members of the genus *Anopheles*, *Culex*, *Mansonia* and *Aedes* are best known for their role in transmitting diseases worldwide (Lamidi *et al*., 2019).

Anopheles species cause malaria which is responsible for approximately 200 million cases and 500,000 deaths annually (WHO, 2018), with the majority of the deaths occurring in young children in sub-Saharan Africa (Aleshnick *et al*., 2020). *Anopheles* species also transmits lymphatic filariasis which affects about 25 million men with hydrocele and over 15 million people with lymphoedema (WHO, 2024). *Aedes* and *Culex* mosquitoes transmit various viral diseases, including dengue, Zika, yellow fever, West Nile encephalitis and chikungunya. *Aedes* mosquitoes are predominantly active during daylight hours, and well adapted to urban living (Kittayapong *et al*., 2017; Dawn *et al*., 2017; Ogunmodede, 2020).

Climatic and weather conditions limit distribution of mosquitoes, and the range of diseases transmitted by them because the biology of the vector is affected (Asgarian *et al*., 2017). To detect, and monitor mosquitoes, surveillance programs are required. Presently, global warming has been pinned as to having significant effects on vector-borne diseases. Biology of mosquitoes is very diverse and climatic variability hasas well led to increased variability in mosquito communities and diseases transmitted by them (Asgarian *et al*., 2017). Climatic changes may affect longevity, activity and spread of vector mosquitoes (Roiz *et al*., 2014; Almeida-Costa *et al*., 2010). Thus, it is one of the most significant global challenges in the world today. Moreover, it is largely caused by anthropogenic activities, and poses significant risks to a broad range of human and natural systems (Agyekum *et al*., 2021). Climate change is being experienced through an increase in global temperatures, sea-level rise, shrinking ice sheets, warming oceans, arctic sea ice decline, glacial retreat, increasing extreme events, ocean acidification, and decreased snow cover (Dantas-Torres, 2015). It may affect human health in many ways, including affecting livelihood and food security (Baars et al., 2023; Agyekum *et al*., 2021). In addition, it could directly influence the patterns of infectious diseases and vector-borne diseases (McIntyre *et al*., 2017) and modify vector distribution and the extension of geographical ranges of mosquitoes such as the malaria vector (Elbers *et al*., 2015). The aim of this study therefore, is to evaluate the impact of climatic factors (relative humidity, temperature, and rainfall) on the abundance of indoor residence mosquitospecies in the study areas.

MATERIALS AND METHODS

Research Design and Study Area

This study is a cross-sectional study in which mosquitoes were collected from bedrooms, and other sleeping places for entomological analysis.

Study Areas

The study was carried out at different locations in Rivers State, which include Okolomade (4.851252^{o}N, 6.489686^{o}E), Emelego (4.821938^{o}N, 6.513129^{o}E) in Odual; and Aluu (4.927203^{o}N, 6.916167^{o}E), Choba (4.886772^{o}N, 6.911554^{o}E), Diobu (4.789705^{o}N, 6.994277^{o}E), and Old Township (4.759892^{o}N, 7.014151^{o}E) in Port Harcourt city metropolis. Rivers State is a coastal state in the Niger-Delta region of Nigeria. It has a tropical rainforest climate, which is defined by a short dry season and a noticeable rainy season that begins in March and lasts until October with a respite that typically occurs in August (Rubel and Kottek, 2010). The majority of the year has very consistent temperatures ranging from a minimum of 21–23^{o}C to a maximum of 28–33^{o}C. Subsistence farming and fishing are typical in many rural villages, and agriculture and industry have a strong position. Common industries include food production, oil and gas extraction, oil and gas servicing, construction, and the marine sector.

Ethical consideration

Advocacy visits were paid to the selected households, and verbal informed consent sort and obtained from community and family

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heads prior to indoor sample collections. Ethical permit was also obtained from the office of the Research and Ethic Committee, University of Port Harcourt.

Sampling and Sampling Techniques

Indoor mosquito collections were carried out every month (March 2022 to February 2023) in each of the areas covering wet and dry seasons from 53 households (21 from Odual and 32 from Port Harcourt). Mosquitoes were collected indoors by pyrethrum spray collection (PSC) from 6.00 am to 10.30 am after the inhabitants have left the rooms. All foods and sensitive materials were properly covered, windows and doors closed and all openings that could allow escape of sprayed insecticide sealed, as health and safety precautionary measures before application of insecticides. Rooms were sprayed in clock-wise direction until a mist was formed. Collected mosquitoes were kept in Petri dishes, each for a room. The Petri dishes were covered with paper tapes, labelled to indicate the site and location, number of persons that slept in the room, and date of sampling. These samples were later taken to the laboratory of the Department of Animal and Environmental Biology, University of Port Harcourt for sorting and identification.

Morphological Identification and Sorting of the Mosquitoes

Mosquitoes were sorted and identified according to the morphological characteristics of their maxillary palps, the patterns of spots on the wings, thorax and terminal abdominal segments, and scales of the legs using the dissecting microscope following the taxonomic keys of Gilles and Coetzee (1987), Edwards (1941) and Harbach (1988).

Climatic Data Collection

Mean rainfall, relative humidity, and temperature were obtained from the Nigeria Metrological Agency (NiMet) from March 2022 to February 2023.

Data Analysis

The results of the study are presented as Tables, Figures and Texts using frequencies and summary statistics such as means, standard deviations and percentages to describe the study population in relation to relevant variables. Linear regression was used to show the association between dependent and independent variables.

RESULTS

Abundance and distribution of mosquito species in the study area

A total of 3311 mosquitoes comprising 16 species, were caught and during the study period. They include *An. gambiaes. l*, *An. funestus*, *An. coustani*, *Ae. aegypti*, *Ae. vittatus*, *Ae. metallicus*, *Ae. stokesi*, *Ae. albopictus*, *Cx. tigripes*, *Cx. horridus*, *Cx. quinquefasciatus*, *Cx. andersoni*, *Cx. pipiens*, *Cx. univittatus*, *Cx. striatipes* and *Cx. Thalassius*. There abundance is as follows; 469(14.16%), 210(6.32%), 85(2.56%), 478(14.39%), 183(5.51%), 116(3.49%), 86(2.59%), 390(11.74%), 159(4.79%), 46(1.39%), 391(11.77%), 160(4.82%), 315(9.49%), 112(3.37%), 78(2.35%) and 43(1.29%) respectively. Of the total sample catched, Port Harcourt recorded an abundance of 1725(51.94%) againstOdual with 1596(48.06%). In Odual, *An. gambiaesl*, 238(15.01%) recorded the highest abundance followed by *Ae. aegypti*, 206(12.99%) while *Ae. stokesi*, 8(0.50%) was the least. In Port Harcourt, *Ae. aegypti*, 274(15.86%) recorded the highest abundance followed by *Cx. quinquefasciatus*, 248(14.38%) while *Cx. thalassius*, 7(0.41%) was the least.

Table 1: Abundance and distribution of mosquito species in the study area

Species	mOdual (%)	Port Harcourt (%)	Total(%)
Anopheles			
An. gambiaes.l.	238(15.01)	231(6.09)	469(14.16)
An. funestus	179(11.29)	31(1.80)	210(6.34)
An. coustani	27(1.70)	58(3.36)	85(2.57)
Aedes			
Ae. aegypti	206(12.99)	274(15.86)	480(14.48)
Ae. vittatus	77(4.85)	106(6.14)	183(5.53)
Ae. metallicus	43(2.71)	73(4.23)	116(3.50)
Ae. stokesi	8(0.50)	78(4.52)	86(2.60)
Ae. albopictus	173(10.91)	217(12.58)	390(11.78)
Culex			
Cx. tigripes	58(3.66)	101(5.86)	159(4.80)
Cx. horridus	33(2.08)	13(0.75)	46(1.39)
Cx. quinquefasciatus	143(9.02)	248(14.38)	391(11.81)
Cx. andersoni	66(4.16)	82(4.72)	148(4.45)
Cx. pipiens	198(12.48)	117(6.78)	315(9.51)
Cx. univittatus	69(4.35)	43(2.49)	112(3.38)
Cx. striatipes	31(1.95)	47(2.72)	78(2.36)
Cx. thalassius	37(2.33)	7(0.41)	44(1.33)
Grand Total	1586(47.90)	1725(52.10)	3311

Monthly abundance and distribution revealed that in Odual, the highest abundance of mosquitoes was recorded in May 339(12.05%) followed by April 345(10.42%) while February 92(2.78%) was the least (as shown in Figure 1). Monthly distribution and occurrence of the mosquitoes indicated that in Odual, the highest abundance was recorded in May (248) followed by July (195), while in Port Harcourt, October (313) recorded the highest while February (43) had the least (Figure 1).

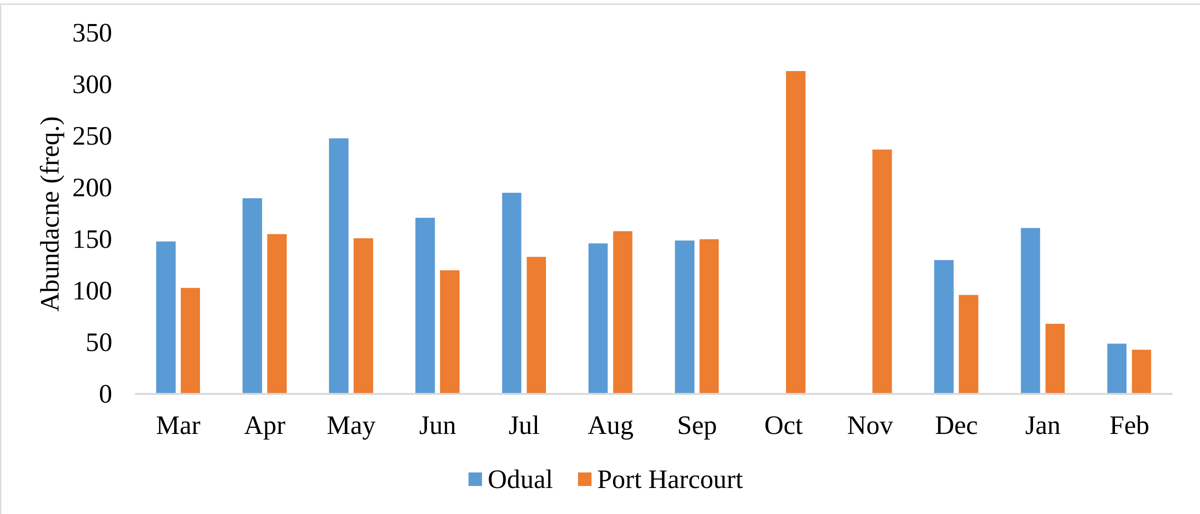

Figure 1: Abundance of mosquitoes in the study locations

The overall monthly abundance of the various species of mosquitoes indicated that in March 2022, *Ae. albopictus*, 47(18.80%) recorded the highest abundance, followed by *An. gambiaesl* 38(15.20%).

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In April, *Ae. albopictus*, 67(19.48) had the highest occurrence followed by *Ae. aegypti*, 63(18.31%) while *Cx. andersoni*, 4(1.16%) was the least. In May, *Cx. pipiens*, 62(15.54%) was the most abundant while *Cx. thalassius*, 8(2.01%) was the least.Ae. aegypti was highest in June, 73(25.09%), September, 56(18.73%) and December, 57(25.33%). Ae. albopictus recorded the highest abundance in July, 65(19.82%); *An. gambiaesl*. In August, 57(18.75%); *Cx. quinquefasciatus* in October, 61(19.49%) and November, 43(18.14%); *Ae. vittatus* in January, 55(24.02%); and *Ae. metallicus* in February, 32(34.78%) as shown in table 2.

Table 2. Overall monthly mosquito abundance in the study

Mosquito species	Mar (%)	Apr (%)	May (%)	Jun (%)	July (%)	Aug (%)	Sept (%)	Oct (%)	Nov (%)	Dec (%)	Jan (%)	Feb (%)
An. gambiae sl	38(15.20)	35(10.17)	57(14.29)	41(14.09)	40(12.20)	57(18.75)	52(17.39)	44(14.06)	28(11.81)	33(14.67)	25(10.92)	19(20.65)
An. Funestus	28(11.20)	17(4.94)	15(3.76)	31(10.65)	8(2.44)	21(6.91)	17(5.69)	8(2.56)	13(5.49)	29(12.89)	23(10.04)	0(0.0)
An. coustani	19(7.60)	7(2.03)	10(2.51)	0(0.0)	14(4.27)	5(1.64)	0(0.00)	3(0.96)	10(4.22)	8(3.56)	0(0.0)	8(8.70)
Ae. Aegypti	29(11.60)	63(18.31)	23(5.76)	73(25.09)	43(13.11)	43(14.14)	56(18.73)	28(8.95)	33(13.92)	57(25.33)	23(10.04)	9(9.78)
Ae. Vittatus	5(2.00)	42(12.21)	21(5.26)	0(0)	16(4.88)	0(0.0)	9(3.01)	18(5.75)	17(7.17)	0(0.0)	55(24.02)	0(0.0)
Ae. metallicus	0(0)	0(0.00)	10(2.51)	0(0)	8(2.44)	27(8.88)	9(3.01)	0(0.0)	18(7.59)	0(0.0)	12(5.24)	32(34.78)
Ae. stokes	8(3.20)	0(0.00)	0(0.00)	5(1.72)	8(2.44)	7(2.30)	17(5.63)	5(1.60)	23(9.70)	13(5.78)	0(0.0)	0(0.0)
Ae. albopictus	47(18.80)	67(19.48)	40(10.03)	23(7.90)	65(19.82)	35(11.51)	56(18.73)	26(8.31)	13(5.49)	0(0.0)	18(7.86)	0(0.0)
Cx. Tigripes	5(2.00)	23(6.69)	40(10.03)	0(0.00)	17(5.18)	11(3.62)	19(6.35)	10(3.19)	0(0.0)	18(8.00)	13(5.68)	3(3.26)
Cx. horridus	0(0.0)	7(2.03)	13(3.26)	0(0.00)	0(0.0)	3(0.99)	0(0.0)	5(1.60)	0(0.0)	13(5.78)	5(2.18)	0(0.0)
Cx. quinquefasciatus	30(12.00)	25(7.27)	46(11.53)	69(23.71)	26(7.93)	45(14.80)	11(3.68)	61(19.49)	43(18.14)	11(4.89)	21(9.17)	3(3.28)
Cx. andersoni	5(2.00)	4(1.16)	10(2.51)	3(1.03)	33(10.06)	27(8.88)	17(5.69)	31(9.90)	0(0.0)	10(4.44)	0(0.0)	8(8.70)
Cx. Pipiens	23(9.20)	27(7.85)	62(15.54)	31(10.65)	29(8.84)	5(1.64)	26(8.70)	48(15.34)	27(11.39)	23(10.22)	13(5.68)	1(1.09)
Cx. univittatus	0(0.0)	18(5.23)	21(5.26)	15(5.15)	21(6.40)	0(0.0)	6(2.01)	8(2.56)	12(5.06)	5(2.22)	3(1.31)	3(3.26)
Cx. striatipes	3(1.20)	9(2.62)	23(5.76)	0(0.00)	0(0.00)	18(5.92)	0(0.0)	15(4.79)	0(0.0)	5(2.22)	0(0.0)	5(5.43)
Cx. thalassius	10(4.00)	0(0.00)	8(2.01)	0(0.00)	0(0.0)	0(0.0)	4(1.34)	3(0.96)	0(0.0)	0(0.0)	18(7.86)	1(1.09)
Total	250	344	399	291	328	304	299	313	237	225	229	92

The impact of climatic factors on the abundance of indoor resident mosquito

The mean rainfall during the study showed that October 2022 (258.3ml) recorded the highest mean followed by June, 2022 (255.1ml) while January, 2023 (2ml) recorded the least. The impact of rainfall on the abundance of indoor resident mosquitoes in Odual, showed a positive linear relationship (linear equation of $y=0.2645x+128.87$; $R^2 = 0.1959$). With a coefficient of determination of (R^2) =0.1959, it means that rainfall contributed 19.59% of the variation of indoor mosquito population. In Port Harcourt, rainfall also, recorded a positive relation with mosquito abundance ($y=0.5068x+82.2$ $R^2 = 0.387$), hence contributed 38.7% of the changes in mosquito abundance (R^2=0.38.7) (Figure 2).

Humidity values within the study period recorded it highest values in July, 2023 (88.9%) while the least was in March, 2023 and February, 2022 (76.1%). The impact of humidity on indoor resident mosquito in Odual ($y=2.5533x-53.044$; $R^2=0.0592$) and Port Harcourt ($y=5.8259x-342.62$; $R^2 = 0.1373$) showed positive linear relationships; and accounted for 5.92% and 13.73% of the variations in indoor resident mosquitoes in Odual and Port Harcourt respectively (Figure 3).

The mean temperature was highest in June, 2022 (27.3ºC) while the least was in August, 2022 (25.6ºC). It recorded a skewed influence on mosquito abundance, with a positive relationship in Odual ($y=19.595x - 366.89$; $R^2 = 0.1463$), and a negative linear relationship in Port Harcourt ($y=-27.434x + 874.19$; $R^2 = 0.1454$) respectively (Figure 4.).

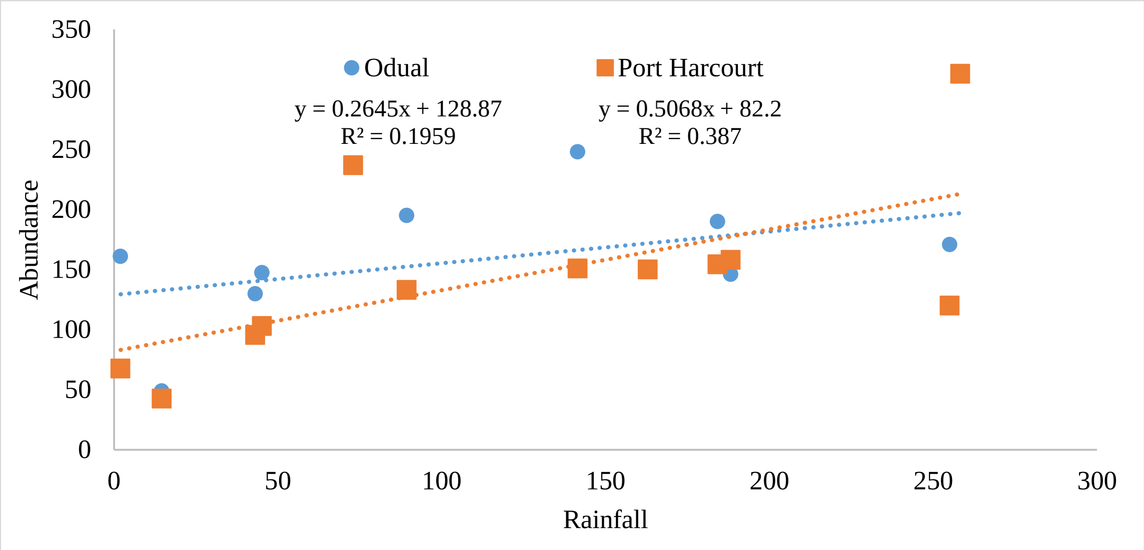

Figure 2: Linear regression of mosquito abundance vs rainfall in Odual and Port Harcourt

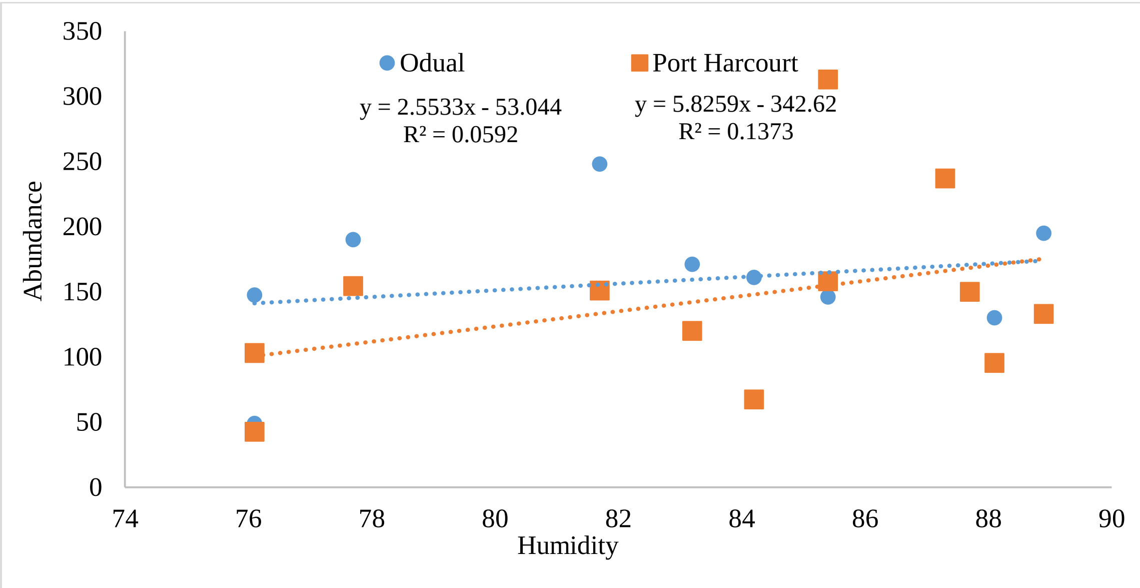

Figure 3: Linear regression of mosquito abundance vs humidity in Odual and Port Harcourt

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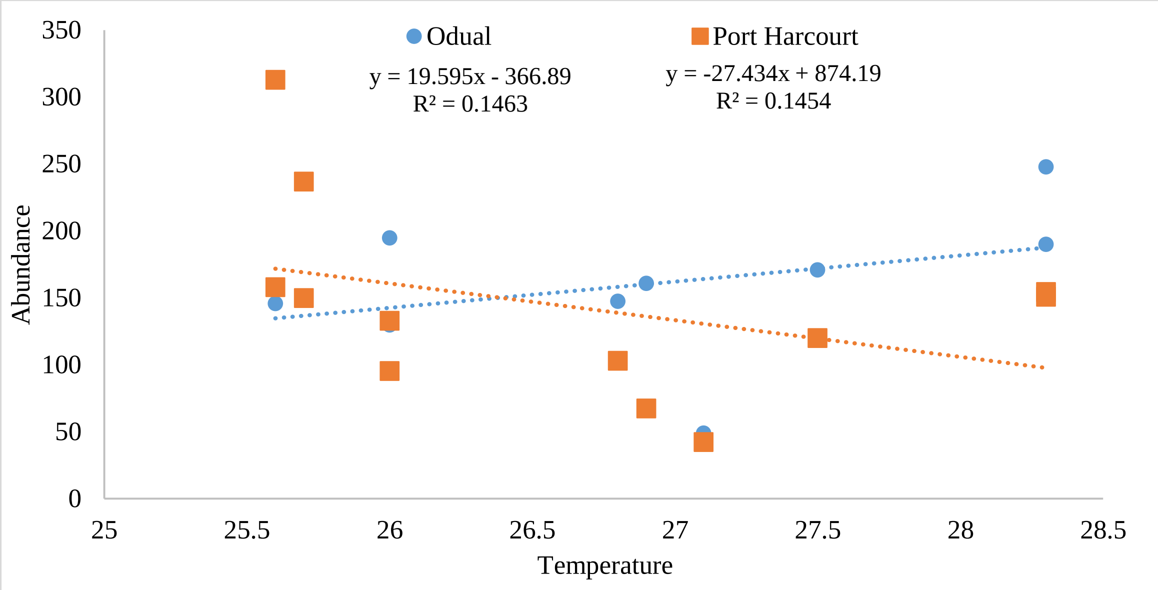

Figure 4: Linear regression of mosquito abundance vs temperature in Odual and Port Harcourt

DISCUSSION

In this study, three *Anopheles* mosquito species (*Anopheles gambiae sl.*, *An. funestus*, and *An. Coustani*), which are vectors of malaria were distributed across the study areas. The data show that *An. gambiae sl.* was the most prevalent species in both Odual (238) and Port Harcourt (231), with a total count of 469 (14.16%). Other studies have similarly reported the dominance of *An. gambiae* in various regions across Africa (Omodior *et al.*, 2021), and in different parts of Nigeria (Madara and Ebuzoeme 2018).

In this study, *Ae. aegypti*out of the five *Aedes*specieswas the most abundant, which is consistent with the findings of Tchouassi *et al.* (2020) in a study conducted in Ghana. The availability of various *Aedes* species in both areas indicate the possibility of an outbreak of Zika virus and yellow fever which are transmitted by *Aedes* mosquitoes. Other *Aedes* species, such as *Aedesvittatus*, *Aedesmetallicus*, *Aedesstokesi*, and *Aedes albopictus*, were also caught in both locations but in lesser numbers. For instance, *Ae. albopictus*, which is avectorof other arboviruses was preponderance in both study areas with 390 individuals (11.78%). Studies from Kenya reported a rise in *Ae. albopictus* populations due to its adaptation to both rural and urban settings (Kamgang *et al.*, 2018). The substantial presence of *Ae. albopictus* in both study locations reflects its invasive nature and ability to colonize new areas, which has been widely documented across African regions.

Culex mosquitoes, which are often implicated for the transmission of lymphatic filariasis and West Nile virus, were also abundant in both locations. The predominant species, *Culex quinquefasciatus*, accounted for 11.81% of the total mosquitoes collected. This finding is consistent with the studies in Ethiopia and Tanzania, where *Cx. quinquefasciatus* dominated mosquito populations in urban and semi-urban settings (Ayala *et al.*, 2017). Other *Culex* species, such as *Cx. tigripes* and *Cx. pipiens*, were also notably in their numbers.

Rainfall is a critical climatic factor that usually influence mosquito breeding by creating habitats for larval development. Stagnant water sources such as puddles, temporary ponds, and containers filled with rainwater provide ideal breeding sites for mosquitoes. In this study, mosquito abundance recorded a positive relationship with rainfall. This observation is similar to the reports by Ferraccioli et al. (2023) in Greece, and Jemal and Al-Thukair (2018) in Saudi Arabia, who respectively reported a positive correlation between rainfall and the abundance mosquitoes. The stronger correlation between rainfall and mosquito abundance in Port Harcourt can be attributed to the urban characteristics of the region. Urban areas tend to have more artificial breeding sitessuch as containers, discarded tires, and stagnant drainage systems that become filled with rainwater, creating ideal habitats for mosquitoes. The species of mosquitoes present in each region may also contribute to the observed differences in rainfall sensitivity. Certain mosquito species such as *Aedes aegypti*, which is more common in urban areas, are highly dependent on rainfall for creating temporary breeding sites. Meanwhile, *Culex quinquefasciatus* and *Anopheles* species can exploit a wider variety of habitats, including semi-permanent and permanent water bodies, reducing their reliance on rainfall. In Port Harcourt, where a higher number of *Aedes* mosquitoes are present due to the urban environment, the stronger correlation between rainfall and mosquito abundance makes a logical sense. On the other hand, in Odual, where the mosquito population were more of*Culex* or *Anopheles* species, the weaker correlation suggests that these species are not as dependent on rainfall for breeding.

Humidity, which is another climatic factor also recorded a positive relationship with mosquito abundance in both locations. A study by Umoh *et al*. (2019) in southern Nigeria, and Nascimento *et al*. (2021) in Brazil respectively reported a positive correlation between humidity and mosquito abundance. The studies showed that mosquito populations increased significantly when relative humidity exceeded 80%, which is a threshold similar to that shown in Odual and Port Harcourt, Rivers State.

The effect of temperature as a climatic factor on mosquito abundance was rather skewed in this study by recording a positive and negative relationships in Odual and Port Harcourt respectively. The increased mosquito abundance with temperature in Odual can be attributed to the rural nature of the region. The areas have more shades, dense vegetative covers that can mitigate extreme heat, allowing mosquito populations to thrive even as temperatures rises. This observation aligns with that of Smith *et al*. (2024) who worked on rural mosquito populations in West Africa and found that rural environments, due to their higher availability of natural breeding sites, allowed mosquito populations to remain relatively stable across temperature variations, with slight increases as temperatures approached 28°C. On the other hand, the decreasing mosquito abundance in Port Harcourt as temperatures rise might be due to the urban environment, where concrete surfaces and limited vegetation can cause heat to accumulate, creating less favourable conditions for mosquito survival. Similar report was made by Drakou et al. (2020) on urban mosquito populations. Higher temperature may have led to the reduction of breeding sites due to lack or few vegetation cover, and many concrete surfaces that adore the greater percentage of land cover in Port Harcourt.

CONCLUSION

The study recorded arrays of mosquito species that are vectors of mosquito-borne infections such as malaria, yellow fever, filariasis, dengue, Zika virus, and others in all the study areas. Rainfall and humidity are critical climatic factors that had positive impact on the mosquito species abundance while temperature had a positive impact in Odual (rural area) but negative impact in Port Harcourt (urban area). We therefore, conclude that People in the study areas, are at risk of mosquito-borne diseases. The knowledge of the impact of climatic factors on mosquito abundance, is a prerequisite for predicting mosquito disease outbreaks, developing effective control measures, and improve surveillance.

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